The Emergence of Relatedness: Exploring Offshore Oil and Gas as well as Offshore Wind Energy in Esbjerg/Denmark

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Abstract

We investigate the emergence of relatedness in the offshore oil and gas industry and the offshore wind energy industry in Esbjerg. We conceptualize the emergence of relatedness between two industries based on firm level search processes which starts from local search (which ignores the other industry), and transforms via explorative search (when first connections to the other industry form) into altered local search (which regularly includes the other industry). Using a case study approach, we show that a technological discontinuity changed organizational search processes and network dynamics network dynamics were responsible for first connections between the two industries. Organizational search processes were altered on a broad level, when interactions and relations between the two industries were institutionalized. This emergence of relatedness also had a distinct geography. First connections were made outside Esbjerg and offshore wind energy firms when Esbjerg was not a center of the offshore wind energy industry. Offshore wind energy firms moved to Esbjerg, after proliferation of relations and geographical co-location of the two industries followed the emergence of relatedness and not the other way around.

Keywords: relatedness, offshore wind energy, offshore oil and gas, structural fold, institutions

1. Introduction

In recent years, relatedness has become a core concept in economic geography (Boschma and Frenken 2011; Boschma and Wenting 2007). Relatedness describes a pattern of innovation and diversification where firms and industries benefit from knowledge transfers from and into, usually, technologically related fields (Breschi et al. 2003, Feldman and Braunerhjelm 2006; Fornahl et al. 2010; Klepper 2007). Due to different, often localized forms of knowledge flows via labor mobility (Breschi and Lissoni 2001), spin-offs (Klepper 2007), knowledge spillovers (Jaffe et al. 1993), and inter-firm relations (Owen-Smith and Powell 2004), relatedness has a particular geography (Boschma et al. 2013).

Although these studies show the benefits of relatedness for regional development (Frenken et al. 2007; Boschma and Iammarino 2009), they do not demonstrate how relatedness emerges at the regional level. So, the typical argument used to explain why actors connect and relate is that of Jacobs' externalities (Jacobs 1969): local economic diversity allows individuals or firms to connect and combine different types of knowledge (Desrochers and Leppala 2011). Yet, Jacobs' externalities do not explain how these connections at the individual level lead to relatedness at the group level, i.e., between two industries or fields. Put differently: an explanation for how relatedness emerges needs to capture how these connections are made not by few, but by many.

This aim requires a perspective on the firm, how it forms connections and under which conditions. As these activities depend on the particular problems for which a firm tries to find a solution, we focus on organizational search processes. Usually, firms' search for solutions within their established capabilities and relations, so-called "local search" (Nelson and Winter 1982; Stuart and Podolny 1996). In contrast, explorative search often spans both technological and relational boundaries (Rosenkopf and Nerkar 2001). Thus, investigating how a firm connects to a new field requires analysis of the conditions under which a firms starts explorative search (e.g., Rowley et al. 2000).

As relatedness between two fields requires many repeated relations, many firms have to search into the other field on a regular basis. Thus, relatedness requires institutionalization of these searches. This institutionalization changes the quality of organizational search also at the firm level. Regular involvement of the other field renders these previously explorative searches as organizationally local. To conclude, we investigate the emergence of relatedness via a change in organizational search processes which starts from local search (and ignores the other industry), and transforms via explorative search (when first connections to the other industry form) into altered local search' (which regularly includes the other industry).

We investigate this topic of change in organizational search processes through a case study concerning the emergence of relatedness between an offshore oil and gas industry and an offshore wind energy industry in the Danish city of Esbjerg. These two industries formed due to transplantation (Martin and Sunley 2006), i.e., operations and technologies were transferred to Esbjerg from firms located in other places. This makes the case suited for researching the emergence of relatedness, as relatedness between the two industries is not inherited. Relatedness between the two industries might be obvious as both industries focus on the establishment of offshore infrastructures. Yet, significant links between them formed only when technical problems at offshore wind farms arose which could not be solved using established search heuristics.

The paper proceeds as follows. Section 2 serves to elaborate the concept of relatedness, and Section 3 conceptualizes the emergence of relatedness as change of organizational search processes. Section 4 describes the research method applied, and Section 5 explains the historical development and current situation of two offshore industries located in Esbjerg. Section 6 investigates how relatedness emerged between these two offshore industries, and in Section 7, we present and explain a three-phase model on the emergence of relatedness. Finally, Section 8 concludes and suggests salient policy implications.

2. Relatedness in Space and Time

The concept of relatedness posits that certain forms of knowledge allow an easier exchange, combination and connection than others. Although there are different types of relatedness such as institutional and social relatedness (Boschma and Frenken 2011), relatedness is most often defined technologically. Additionally, relatedness is a group-level concept and describes relations between aggregate forms such as industries and clusters; and relatedness between two industries exists if they share a common knowledge base or have resembling technological principles (Breschi et al. 2003).

Relatedness between two industries has several forms. Relatedness facilitates diversification (Breschi et al. 2003), knowledge exchange (Nooteboom 1999) and labor mobility between two industries (Timmermans and Boschma 2014). These three forms have particular spatial expressions. Frenken and Boschma (2007) show that diversification of, and spinoffs from, established firms into new fields is a basic dynamic of regional economic evolution. Neffke et al. (2011) revealed that regional industries diversify into related industries. Boschma et al. (2013) put forward that these related industries also had to exist at the regional and not at the country level. Castaldi et al. (2015) concluded that relatedness enhances innovativeness at the regional level. Timmermans and Boschma (2014) showed that intra-regional labor mobility between related industries has a positive impact on productivity growth. These examples show that relatedness is usually a regional level phenomenon (Boschma et al. 2013).

Furthermore, relatedness between industries changes over time. Before regional industries develop their own specific assets and supporting institutions, they depend on knowledge transfers from established and related industries (Storper and Walker 1989). Well-described examples of this are the tire industry in Akron that emerged upon firms with experience in rubber production (Bünstorf and Klepper 2009), the automobile industry in Detroit, which is based on firms in coach and bicycle manufacturing (Klepper 2007) and the environmental technology industry in the Ruhr area that developed out of the declining coal and steel industry (Grabher 1993). However, along the evolution of regional industries, the benefits of related regional industries decreases and they increasingly evolve upon a distinct knowledge base as well as distinct search and problem solving heuristics (Boschma and Wenting 2007; Klepper 2007; Storper and Walker 1989).

In addition what is considered as related, changes over time. Neffke et al. (2011) found by analyzing how regions diversify over time that new forms of relatedness emerged with new industries. Castaldi et al. (2015) showed that relatedness emerges due to breakthrough innovations that connect previously unconnected technologies. Moreover, industries might face technological discontinuities (Anderson and Tushman 1990) that can severely affect their knowledge base (Christensen and Rosenbloom 1995), and in doing so, which industries are related and how they are related changes over time. For instance, 3G mobile phones depend more on software and multimedia than earlier generations of mobile phones, where hardware was more important (Dalum et al. 2005). Accordingly, software firms became more closely related to the mobile phone manufactures. Thus, the relevance of relatedness and what is related differs at the regional level and changes with industry evolution and technological development.

3. Relatedness and Organizational Search

For relatedness to emerge, previously unconnected fields have to be connected. Thus, investigating the emergence of relatedness requires an exploration of how firms form relations. These relations have to form over cognitive distances (Nooteboom 1999; Menzel 2015) to previously unconnected industries (Castaldi et al. 2015) and to proliferate to actually connect different industries.

Many studies show the benefits organizations accrue when they venture into new areas and form relations in new fields (Teece et al. 1997; March 1991). However, a search for solutions usually takes place within established competencies (Stuart and Podolny 1996), along established search heuristics (Dosi 1982), and established relations (Rowley et al. 2000). Thus, firms search organizationally local (Nelson 1993; Stuart and Podolny 1996). Katila and Ahuja (2002, 1184) describe organizationally local search as follows: “organizations that search locally address problems by using knowledge that is closely related to their preexisting knowledge base.” Stuart and Podolny (1996) suggest three reasons why organizational search processes are overwhelmingly local: due to bounded rationality firms do not have complete knowledge of the range of possible solutions; firms repeat search behaviors that worked well to solve prior problems; and research will produce better results when it is based on established competencies.

In contrast, explorative search entails high costs and unclear outcomes (March 1991). Despite these disadvantages, firms search exploratively for several reasons. March (1991) argues that firms need to do so to maintain long-term competitiveness. Rowley et al. (2000) described how firms apply explorative strategies to cope with changing environmental conditions and Menzel et al. (2017) show that a particular institutional setting can reward explorative search. Thus, firms apply different forms of organizational search in different situations. Furthermore, firms learn by permanently searching in a particular industry. Previous searches make subsequent search easier, as firms built up respective capabilities and establish relations in the other industry (Stuart and Podolny 1996). Thus, repetition renders explorative search local (Rowley et al. 2000).

To summarize, relatedness between two fields can be described by organizational search processes and the emergence of relatedness can be described as changes in search processes. If two fields are unrelated, search in the other field takes place only arbitrarily and remains explorative. Relatedness emerges when search in the other field becomes organizationally local by repetition. In other words, relatedness emerges as organizational search processes change from local search (which ignores the other field) via explorative search (which forms connections to the other field) to local search' (which involves the other field).

Search processes can be distinguished by the resulting relations. While local search takes place within established relations (Stuart and Podolny 1996), explorative search takes place outside established relations (Rosenkopf and Nerkar 2001). Additionally, research indicates a particular geography behind the formation of relations over relational and technological boundaries. If relational and technological distances have to be bridged, being located in geographical proximity can help (Menzel 2015). Ter Wal (2013) shows that network formation in new industries follows social relations, which are often locally bound. Owen-Smith and Powell (2004) show that the probability of two organizations forming a tie is twice as high when they are located in the same region. Thus, being geographically close facilitates the establishment, proliferation and maintenance of relations between two industries.

Search processes are also affected by the institutional setting in which they take place. Bathelt and Glückler (2014, 341) define institutions as "stabilizations of mutual expectations and correlated interaction.” An institutionalization of search processes in the other field would imply that firms expect that search processes in the other field are successful, that they share this expectation with other firms, and act accordingly. Additionally, these expectations and interactions are stabilized, for example via organizations that support these search processes in the other field (Malmberg and Maskell 2002). In the wake of this, studies show how differences in institutional settings result in different forms of relatedness (Boschma et al. 2013; Boschma 2017). Boschma and Capone (2015) describe how institutions mediate the relevance of relatedness; they use a Varieties of Capitalism approach (Hall and Soskice 2001) to show that relatedness is more important in coordinated market economies than in liberal market economies. Garud and Karnøe (2003) describe how wind turbine industries in Denmark and the US emerged upon different related industries: aviation in the US and agricultural machinery in Denmark. At the regional level, Peck and Theodore (2007) as well as Malmberg and Maskell (2002) argue that regional institutional solutions emerge due to particular intra-regional coordination problems; this line of reasoning explains differences in relatedness at the regional level by differences in regional institutions.

To conclude, we conceptualize relatedness as resulting from organizational search processes. Relatedness emerges when search processes change from local search (which ignores the other industry) via explorative search (which forms connection to the other industry) to altered local search’ (which includes the other industry). These search processes can be distinguished in terms of how firms from one industry form relations with the other industry and how these connections are mediated by the institutional environment.

4. Method

This paper builds on an explanatory case study (Yin 2013) investigating how relatedness emerged between the offshore oil and gas industry and the offshore wind energy industry in Esbjerg. The decision to apply a case study to pursue this avenue rests on three reasons. First, a case study is suitable to map what type of knowledge that is transferred by whom and with what consequences between the two offshore industries over time to account for the emergence of relatedness (Boschma 2017). Second, a case study is appropriate to examine the context in which relatedness emerges such as the importance of institutions, the availability of resources and the role of change agents (Boschma 2017). Third, a case study allows openness to explore the geographical dimensions at which relatedness can emerge (Castaldi et al. 2015).

In terms of case selection, the two offshore industries that together make up the case study are specifically chosen because they result from transplantations (Martin and Sunley 2006). This means that the industries are not genealogically connected, and relatedness is therefore not inherent, which make them ideal when investigating the emergence of relatedness. Thus, this situation of two non-genealogical industries in the same location, which start to exchange knowledge and collaborate is relatively rare, and that justifies calling the case study for an extreme case study (Flyvbjerg 2006).

Data for the case study is acquired in two phases in the period of April 2012 to May 2018. In phase one, 27 personal interviews were made with the purpose of obtaining a rich understanding of the context in which the two offshore industries are embedded. The interviewees represent a broad range of actors from and related to the industries (see Appendix), and the interviews focused on these four themes: the development of the offshore industries, the geography of the offshore industries, the agenda in the offshore industries as well as the actors, resources and activities within the offshore industries.

In phase two, 13 personal interviews and one focus group interview were completed. The personal interviews were done with the aim to gain a deep insight into the knowledge transfer between the two offshore industries, and the focus group interview was conceived to present and challenge the findings from the personal interviews. The interviewees for this line of interviews were chosen based on their industry acumen and their experience with and involvement in the knowledge transfer between the two industries. This resulted in a group of primarily senior management people from most key actors in both industries (see Table 1). The interviews focused on four themes inspired by the theoretical framework outlined earlier in the paper: knowledge sources, individual and industry search processes, knowledge transfer and learning as well as relation building.

All 41 interviews followed a semi-structured interview guide with open-ended questions, which allowed flexibility to pursue new discoveries during the interview sessions. Each interview lasted between 30 minutes and 1 hour, except from the focus group interview, which lasted 2 hours. The interviews in phase one were due to practicalities outlined in the form of a summary, whereas the interviews in phase two were recorded.

The analysis of the interview data happened along two steps. First, after each interview key statements were highlighted and if possible validated using sources such as web pages, press releases, consultancy reports and industry magazines. After this immediate and basic data analysis, a pattern coding process (Saldaña 2016) was initiated with the purpose of searching for causes and explanations in the data for the emergence of relatedness between the two offshore industries. This inductive coding process resulted in the identification of several time periods, events, actors, resources and activities that are significant for explaining not only the emergence of relatedness but also the enclosed consequences. Based on these two steps, the case description presented in Section 6 was written.

Finally, industry and energy experts and professionals have commented on different versions of the case description to minimize errors and increase validity. In addition, the reliability of the case study findings has been addressed by developing a case study protocol, where all actions in the data acquisition and data analysis were carefully documented. The protocol consists of the following five sections, which makes it straightforward for other researchers to repeat the study: subject matter, research question, e-mail communication with the interviewees, interview guides, and notes from the interviews. This increases the transparency of the research process.

5. The Offshore Oil and Gas Industry and the Offshore Wind Energy Industry in Esbjerg

Esbjerg has been an important harbor city on the Danish west coast since the 1870s. After the Second World War and up to the 1970s, fishery, shipbuilding and container shipping made up the industrial base of the city (Hahn-Pedersen 2001). During the 1970s and the early 1980s Esbjerg changed its industrial base because of the opening of several oil and gas fields in the Danish part of the North Sea (Hahn-Pedersen 2001). Due to these activities, a regional offshore oil and gas industry emerged, which focused on locating and extracting oil and gas resources. While fisheries, shipbuilding and container shipping were of regional importance, the offshore oil and gas activities made the city a location of national and international importance. Around the millennium, the industrial base of Esbjerg changed again. Following a decision by the Danish parliament in the early 1990s to build a large-scale offshore wind farm in the North Sea, an offshore wind energy industry developed in Esbjerg (Langkilde et al. 2015).

Today both regional industries are leading within their separate fields of specialization. The offshore oil and gas industry provides close to 9,500 jobs in Esbjerg, while the offshore wind energy industry provides roughly 4,000 jobs in Esbjerg (Esbjerg Erhvervsudvikling 2016). The core of the offshore oil and gas industry is constituted by several multinationals, including these four oil and gas contractors: Maersk Oil, DONG Energy, Wintershall, and Hess Corporation. The offshore wind energy industry is mainly centered around the activities of the wind turbine manufactures MHI Vestas and Siemens Gamesa and the wind energy contractors DONG Energy and Vattenfall. Additionally, several knowledge intensive business service providers such as the engineering consultants Rambøll and COWI, as well as the certifier DNV GL participate in both industries.

Despite the different specializations of the two industries, they enjoy extensive connections. Knowledge exchanges refer to production as well as offshore installations and maintenance. Industry and regional business promotion organizations provide new organizational forms, forums and projects to coordinate knowledge exchange between the two industries. Research and educational organizations have established a shared knowledge base regarding e.g., offshore energy systems and offshore safety matters. Labor mobility between the two industries is frequent and, particularly, specialized suppliers from the offshore oil and gas industry have diversified into the younger offshore wind energy industry. Thus, the two industries exhibit the knowledge exchanges, labor mobility and firm diversifications that would be expected from related industries.

Yet, these connections had to form over time, as the younger offshore wind energy industry branched from the onshore wind energy industry had no roots in Esbjerg or in the regional offshore oil and gas industry and (Markard and Petersen 2009). With the emergence of an offshore wind energy industry in Denmark, wind turbine producers and specialized suppliers moved offices or company functions to Esbjerg. Thus, the offshore wind energy industry in Esbjerg emerged upon what Martin and Sunley (2006) call "transplantation from elsewhere". To conclude, there was no connection between the offshore wind energy industry and the offshore oil and gas industry at the beginning and the manifold interchanges between the two regional industries were far from being expected.

6. Organizational Search Processes and Relations between Offshore Oil and Gas and Offshore Wind Energy

In this section, we outline how the offshore wind energy industry and the offshore oil and gas industry in Esbjerg became related. In order to do this, we focus on wind energy firms and investigate how their search processes changed from local search (which ignores oil and gas) via exploration (which forms connections with the other industry) to altered local search' (which involves the oil and gas). This tripartition structures the following case presentation.

6.1. Local Search until 2004

At first glance, offshore wind turbines do not differ much from onshore wind turbines. Both consist of components such as blades, towers, nacelles, gearboxes, control systems, and generators. The only substantive difference is the foundation structure since offshore wind turbines need to be mounted onto the sea floor. Nevertheless, offshore wind turbine production branched off from onshore wind turbine production (Markard and Petersen 2009): wind turbine producers separated offshore from onshore activities, not all onshore producers moved toward offshore and wind turbine producers emerged that produced solely offshore wind turbines. As a result, offshore wind turbine production became a distinct industry (Sommer 2015).

Before offshore wind energy became a distinct industry, the first commercial offshore wind turbines were installed by onshore wind turbine producers and the first offshore wind farms in the world were installed in Denmark: Vindeby was planned in 1989 and finished in 1991. It was located at the entrance to the Baltic Sea. Tunø Knob was installed in the Kattegat in 1995. Bonus/Siemens[1] equipped Vindeby with eleven 450kW turbines and Vestas provided ten 500kW turbines for Tunø Knob. Both manufacturers used turbines originally designed for onshore installation and mounted them on foundation structures produced by specialized suppliers. The wind turbines in both of the wind farms performed well. Indeed, they exceeded their planned operation time of 20 years and there was no reason to assume that organizational search processes and routines suitable to produce onshore wind turbines were insufficient to produce offshore wind turbines.

The next Danish offshore wind farms that were established were Middelgrunden in 2000 and Horns Rev 1 in 2002. These wind farms were considerably larger in turbine effect and overall size compared to their predecessors in the 1990s. Bonus/Siemens produced twenty 2MW

[1] Bonus Energy was acquired by Siemens in 2004. To avoid confusion and to emphasize that Bonus Energy and Siemens Wind Power are actually the same firm, we use the name Bonus/Siemens. We ignore that Siemens Wind Power and Gamesa Corporación Tecnológica merged in 2017 as the developments we describe took place prior to this. In addition, Vestas' offshore division changed to MHI Vestas in 2014 and DNV to DNV GL in 2013. In these cases, we use the names that were valid in the respective years.

wind turbines for Middelgrunden; a further eighty 2MW wind turbines from Vestas were for Horns Rev 1. Yet, Horns Rev 1 differed from the three previous wind farms in one important aspect: Horns Rev 1 was installed in the North Sea. Figure 1 shows how this location changed the environmental conditions under which the turbines operated; the wind turbines at Horns Rev 1 were installed in deeper waters, further away from shore, and were subject to higher wind speeds and stronger waves than the other three wind farms.

These environmental conditions caused significant damage to the wind turbines at Horns Rev 1. In 2004, Vestas had to remove all nacelles, because the gears, transformers, blades and generators, among other things, could not withstand the offshore weather conditions, and later between 2006 and 2010, crumbling wind turbine foundations were discovered. Cementing the crossing between the monopile and the transition piece caused inflexible structures that could not bear the changing loads under offshore weather conditions. This procedure of cementing was normal for other water-based installations like bridges and harbors and the same foundations worked well at the Middelgrunden wind farm. In sum, organizational local search was sufficient to solve problems for near shore wind farms in the Kattegat and at the entrance to the Baltic Sea. Yet, the example of Horns Rev 1 showed the limits of local search when producing wind turbines for the conditions at the North Sea.

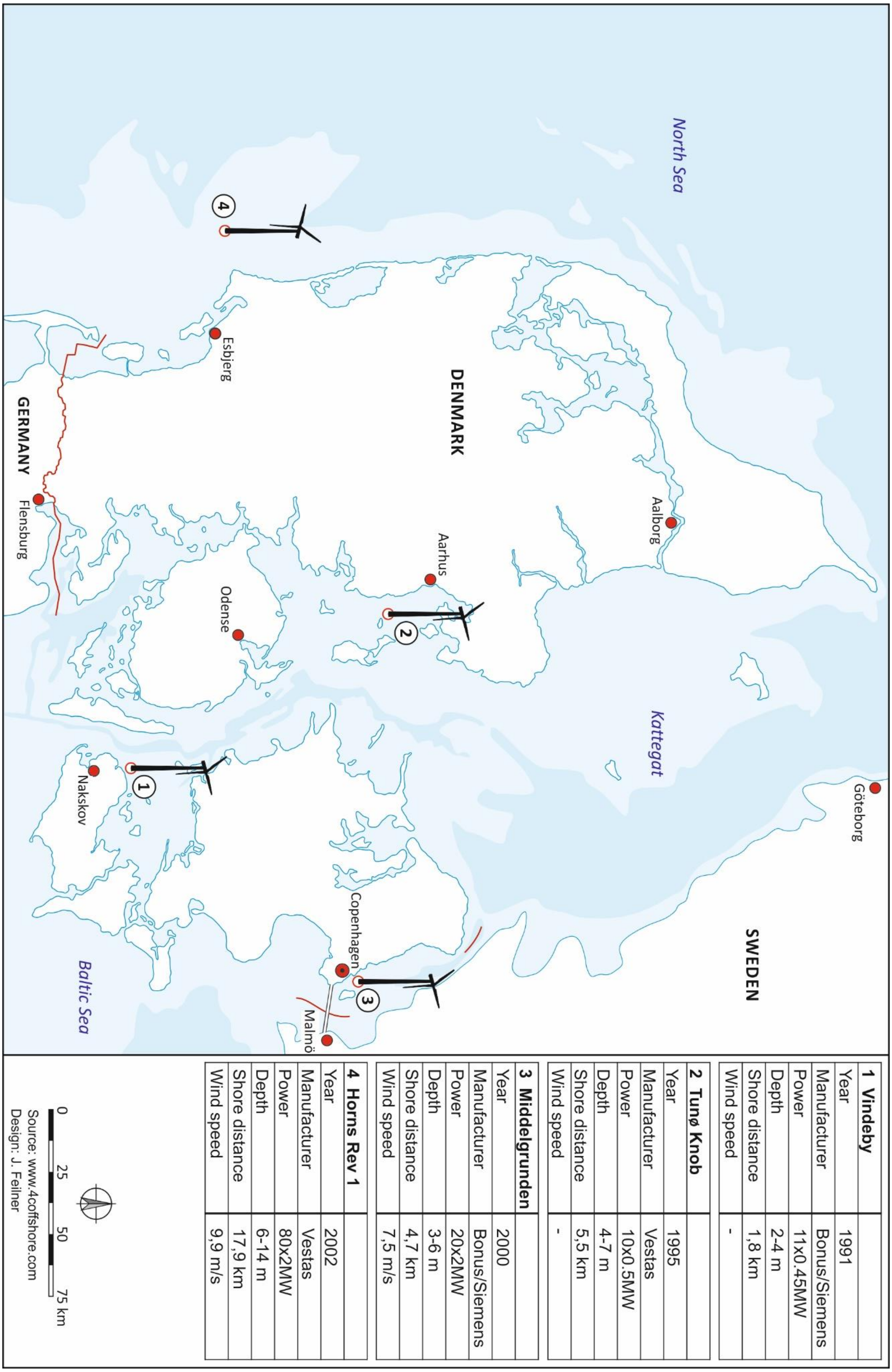

Figure 1: Location and Size of the First Four Danish Offshore Wind Farms

Since the four offshore wind farms were installed in different locations in Denmark, there was no national center for the offshore wind turbine industry. Horns Rev 1 was the first offshore wind farm to use Esbjerg as an installation port, i.e., the harbor from which offshore wind turbines could be disembarked, installed and maintained. Esbjerg was chosen as the installation port because of its existing physical infrastructure from the offshore oil and gas industry as well as its proximity to the location of the offshore wind farm. The three other offshore wind farms were installed via Onsevig or Copenhagen.

As a consequence of these scattered locations, only few offshore wind energy firms were located in Esbjerg during that time. Vestas, as the provider of turbines for Horns Rev 1, opened an office in 2000, but turbine assembly took place at locations that also produced onshore wind turbines. Furthermore, Bonus/Siemens did not have a regular office in Esbjerg before 2012. DONG Energy, as operator of Horns Rev 1, already had an office for its offshore oil and gas activities, which has also included a branch for offshore wind energy since 2002. Knowledge intensive business service providers like DNV, COWI and Rambøll already had offices in Esbjerg. Yet, these offices were related to offshore oil and gas or other activities and the companies coordinated most of their offshore wind energy activities from their head offices in Fredericia or Copenhagen. Therefore, when organizationally local search processes were prevalent in the offshore wind turbine industry, Esbjerg was far from being a center of the industry.

6.2. Patterns of Non-Local Search since 2005

The above-mentioned damage at Horns Rev 1 made it obvious that knowledge to produce onshore wind turbines was not sufficient to produce reliable offshore wind turbines, which resulted in explorative search processes. In 2005, DONG Energy and Rambøll started to apply knowledge from the offshore oil and gas industry to problems in the construction of offshore wind farms. The solutions found in the offshore oil and gas industry were often quite simple. For example, in the beginning, short bolts were used to construct offshore wind turbines as they had proved to be sufficient for onshore wind turbines. Yet, they could not bear the loads of the offshore weather conditions and parts began to fall off. As a result, long bolts that have proven their reliability in the construction of offshore oil and gas installations were used instead. A further example is coating. Coating is necessary to protect offshore wind turbines from corrosion, but the one layer of coating that was used for onshore wind turbines proved insufficient for offshore conditions. Thus, two layers of coating, that was standard in the offshore oil and gas industry, also became the standard in the construction of offshore wind turbines.

The firms that firstly recognized how knowledge from the offshore oil and gas industry could help to solve the problems in the offshore wind energy industry where firms that were involved both in Horns Rev 1 and in offshore oil and gas projects: DONG Energy as operator of Horns Rev 1 had experience from running the oil and gas fields at Syd Arne-feltet (in 1999) and Siri-feltet (in 1999), and Rambøll was involved in Horns Rev 1 as an engineering consultant and had designed and planned the offshore oil and gas projects at Halfdan-feltet (in 1999) and Syd Arne-feltet (in 1999). In each firm, engineers with experience in both industries, either through labor mobility or internal rotation made this connection.

Additionally, like DONG Energy and Rambøll, other firms that were involved in both industries such as the engineering consultancy COWI (involved in the offshore wind farms at Vindeby and Middelgrunden and the offshore oil and gas project at Syd Arne-feltet) and the certifier DNV (certified all four offshore wind farms and all offshore oil and gas projects in the Danish part of the North Sea) started to transfer knowledge from the offshore oil and gas industry to the offshore wind energy industry. DNV, for example, participated in the process of transferring and adapting standards for health and safety like OHSAS (working environment) and GWO (basic safety training) that were originally developed for operations in the offshore oil and gas industry, which are now implemented at most firms in the offshore wind energy industry.

Moreover, these firms that were involved in both industries also started to connect offshore wind energy firms with offshore oil and gas firms. In 2006, DONG Energy, Rambøll and COWI connected Vestas and Bonus/Siemens with oil and gas service providers. Via this connection, the offshore wind turbine manufacturers acquired knowledge regarding the maintenance of offshore wind turbines such as service guidelines for offshore installations as well as transportation systems that allow maintenance despite bad weather conditions. Overall, knowledge along the categories of offshore wind turbine construction, installation and maintenance as well as offshore health and safety was transferred via these relations from the offshore oil and gas industry to the offshore wind energy industry.

This formation of relations coincided with the relocation of offshore wind energy activities to Esbjerg. Around 2005, firms such as Rambøll, COWI and DNV moved some of their offshore wind energy activities to their established offices in Esbjerg. Vattenfall established an office in 2006 due to its new involvement in Horns Rev 1, and with the offshore wind farm in Lynn and Inner Dowsing (in 2008, United Kingdom) and Horns Rev 2 (in 2009, Denmark), Esbjerg also became the installation port for Bonus/Siemens. Yet, Bonus/Siemens managed these activities from its headquarters 80 km away, in the city of Brande.

This phase of exploration was also shaped by intensifying labor mobility from the offshore oil and gas industry to the offshore wind energy industry. In the beginning, this labor mobility was not local and the two labor markets were geographically separated. Employees that moved from the oil and gas industry to the offshore wind energy industry usually moved from Esbjerg to other locations, especially Copenhagen and the Central Denmark Region. As firms started to locate more and more offshore wind energy functions to Esbjerg, labor mobility between the two industries also increasingly took place within the city.

6.3. Institutionalization of Local Search' since 2010

The phase from 2010 and on is marked by a proliferation of supporting organizations in Esbjerg. New organizational forms such as projects, forums, and industry supporting organizations appeared with the aim to initiate and stabilize relations and interconnections between the two offshore industries in Esbjerg. The following is a summary of those organizations that had the greatest impact on connecting the two industries.

One of the first of these organizational forms was the project Energi på Havet (Offshore Energy). This project was initiated by the industry supporting organization Offshore Center Denmark, which was originally formed by Esbjerg-based oil and gas firms in 2003. This project also involved, among others, local and regional business supporting organizations, Vattenfall, Rambøll, COWI, and the Esbjerg-based universities: University of Aalborg and University of Southern Denmark. The Energi på Havet project investigated how the two offshore industries could learn from each other and how offshore-oriented education could be improved (Offshore Center Denmark, 2015). The project lasted until 2013.

In the wake of this project and due to interest expressed in industry and policy circles, Offshore Center Denmark, which initiated Energi på Havet, was transformed into the industry supporting organization Offshore Energy. Actors outside Esbjerg like Syddansk Vækstforum (Growth Forum of Southern Denmark), the offshore energy test facility LORC (Lindoe Offshore Renewables Center) and the Danish Wind Industry Association drove this transformation and became key stakeholders in Offshore Energy. One of the main tasks of this organization is to organize knowledge transfer between the two offshore industries via knowledge sharing seminars and match-making events as well as help fostering collaboration within and across the two industries through common projects and innovation forums. Furthermore, local research and educational organizations such as the University of Aalborg, University of Southern Denmark, Business Academy Southwest and the Frederica School of Marine and Technical Engineering support knowledge transfer by providing a knowledge and training infrastructure for both industries. That includes for example two education programs, Offshore Energy Systems and Risk and Safety Management from 2013 and 2014 respectively, which are co-organized by the two universities.

With these new organizational forms, knowledge transfer from the offshore oil and gas industry to the offshore wind energy industry in the three areas of offshore wind turbine construction, installation and maintenance as well as offshore health and safety increased in complexity. Regarding health and safety, even a shared knowledge base emerged. In addition, knowledge transfer also changed direction. Around the year 2011, Rambøll and COWI, active in both industries, started for instance to apply calculation techniques and software used for modeling, designing and optimizing offshore installations in the offshore wind energy industry to projects in the offshore oil and gas industry.

The pervasiveness of these knowledge exchanges indicates altered organizational search processes from local search to local search’. Search in the other industry regularly took place in areas in which firms in the other industry had particular expertise. For example, the offshore oil and gas industry has long established competencies in constructing, installing, and maintaining offshore installations that are able to endure the environmental conditions in the North Sea. As a result, offshore wind energy firms search in the regional offshore oil and gas industry with the aim to make offshore wind turbines more reliable, facilitate their installation and improve maintenance. In turn, offshore wind turbine manufacturers have more experience in batch production and production cost minimization. Thus, offshore oil and gas firms search in the local offshore wind energy industry for solutions to improve production processes through standardization and organizational procedures. To conclude, knowledge exchanges between the two industries are complementary or result in a shared knowledge base, as was the case regarding offshore health and safety.

Additionally, the proliferation of organizational forms since 2010 indicates that search in the other industry was not an isolated event. Instead, it was institutionalized. Organizations such as universities, business or industry supporting organizations support these search processes. It is important to note that these organizations and their initiatives formed as a result of enhanced knowledge flows between the two offshore industries. In this respect, the formation of these organizations is an indicator of institutionalized exchange between the two industries.

During this phase of institutionalization, organizational search processes became increasingly geographically local. Not only were new organizational forms established in Esbjerg that affected organizational search processes, organizations outside of Esbjerg pursued initiatives in Esbjerg and in doing so further condensed knowledge exchanges on Esbjerg. This proliferation of organizational forms in Esbjerg since 2010 institutionalized regular search processes in specific areas of the other industry on the local level.

7. The Emergence of Relatedness

The case study revealed that the emergence of relatedness between the offshore oil and gas industry and the offshore wind energy industry followed a sequence of three phases: a first phase of local search (which ignores the other field), a second phase of explorative search (when first connections form), and a third phase where local search' (which includes the other field) was institutionally stabilized. The first phase starts with local search and ends when local search is no longer sufficient to solve particular problems. In the example of the offshore wind energy industry, local search lasted from 1989, when planning for the first offshore wind energy farm at Vindeby started, until problems at Horns Rev 1 began in 2004. The second phase of explorative search began in 2005, when firms such as DONG Energy and Rambøll and later COWI and DNV started to apply knowledge from the offshore oil and gas industry to the offshore wind energy industry. The first tangible knowledge that was transferred between the two offshore industries was quite simple. This result contradicts research that claims that breakthrough innovations result from connecting distant knowledge (Phene et al. 2006; Castaldi et al. 2015).[2] However, it accords with research that supposes that this transfer is easier when the knowledge is simple and easy to comprehend (Menzel 2015). The third phase started with the establishment of many organizational forms such as projects, forums, and industry supporting organizations in Esbjerg from 2010 onwards. We interpret the proliferation of organizational forms as an indicator of the institutionalization of organizational search processes in the other industry. As relatedness is a group level concept, it is this institutionalization of altered local search' through which relatedness is performed.

The case study also revealed three particularities that went beyond our assumptions and affected organizational search and the emergence of relatedness. These particularities are the

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[2] It has to be mentioned that these studies base in patent data and that first knowledge transfers between offshore wind and offshore oil and gas were surely not eligible for patents.

sudden industry wide change from local to explorative search, the network dynamics involved in connecting both industries, and the changing geography of actors and relations during these three phases. The first particularity refers to the pervasive change from organizationally local to explorative search processes. The phase of local search lasted from 1989 until 2004. These fifteen years testify to the persistence of organizationally local search and respective relations despite availability of better solutions in other fields. This phase ended quite abruptly following the damages at Horns Rev 1. These damages were not perceived as a problem specific to Vestas which installed the turbines, but as industry problems. Studies show that problems that are considered industry specific and not firm specific have a particular structure and can be described by technological discontinuities (Anderson and Tushman 1990). Such technological discontinuities are not necessarily radical innovations since they often comprise only few changes in the design of a product, in the product architecture or in a production process (Henderson and Clark 1990). These technological discontinuities often change an industry's knowledge externalities, which also affects the evolution of regional industries. Østergaard and Park (2015), for example, describe how the Danish wireless cluster had difficulties adapting to the technological discontinuity from 2G to 3G telecommunications, which demanded closer relatedness to software and multimedia domains. As technological discontinuities enforce industry wide explorative search processes of incumbent firms, we expect that the end of the phase of local search is generally connected with technological discontinuities.

The second particularity stems from the network dynamics that were involved in the connection of the two industries. The first firms that connected the two industries were DONG Energy, Rambøll, COWI, and DNV. These four firms were especially suited to do so, as they inhabited a particular network position: a structural fold. Vedres and Stark (2010) describe a structural fold as a position where actor A is involved in different cohesive groups.

In contrast to a structural hole, where actor A is able to benefit from arbitrage between unconnected actors B and C (Burt 1992), the position at the structural fold includes not only the relation to otherwise unconnected actors B and C, but relations to the entire cohesive group. Therefore, actor A not only knows actors B and C, but also all other actors that are tightly connected to either actor B or C. This involvement in different cohesive groups deems an actor at the structural fold a multiple insider and allows a deep understanding about diverse fields. In our case, the position at a structural fold and respective intra-firm labor mobility enabled engineers in firms like DONG Energy, Rambøll, DNV and COWI to recognize the value of knowledge from the offshore oil and gas industry in order to navigate and mitigate the reliability problems of offshore wind turbines.

Moreover, these firms at the structural fold started a process that Obstfeld (2005) calls tertius iungens i.e., the 'third who joins': firms such as DONG Energy and Rambøll connected firms like Vestas and Bonus/Siemens with firms in the offshore oil and gas cluster. Tertius iungens is based upon a network dynamic where previously unconnected actors are connected via introduction of a third actor that is connected to both. This connection to friends of friends describes that new connections are easier when network distances are already small (Watts 2004; Ter Wal 2013). Tertius iungens, in addition, describes why actors intentionally connect previously unconnected actors, namely to improve innovativeness at the group level (Obstfeld 2004). We assume that relatedness emerges upon a combination of both a network position and a strategy, namely actors at structural folds that apply tertius iungens strategies. Via their involvement in different cohesive groups, actors at structural folds are in a special position to connect these groups.

The third particularity refers to the geography of relations between the two industries. When initial connections were established and labor mobility started from one industry into the other, actors were geographically dispersed. These exchanges became geographically proximate when firms and their respective activities moved to Esbjerg. Therefore, network dynamics were responsible for the connection between the two industries and geographical proximity was created afterwards. Yet, there is support for an argument that the network processes that were crucial in our case study context take place especially in geographical proximity. For example, the position of an insider in different cohesive groups is easier to achieve and maintain when these groups are in geographical proximity. Grabher (2002), for example, described how geographical proximity facilitated the involvement of the London advertisement industry in different projects and groups. Also triadic closure via tertius iungens has its particular geography. Especially in networks in young industries, triadic closure follows social relations, which are often regionally bound (Sorenson 2003, Ter Wal 2013). Thus, there are good reasons why relatedness between two industries could emerge at the regional level. Our study showed that both paths are possible: relatedness that is facilitated by geographical proximity and geographical proximity that results from constructing relatedness.

In the third phase, local interactions intensified as an institutional environment emerged that supported exchanges between these two industries at the local level. This is in accordance with literature that argues how institutional solutions are found at the regional level to solve particular coordination problems (Peck and Theodore 2007, Malmberg and Maskell 2002). Additionally, actors at particular network positions did not seem to play a role and relations were pervasive; at least in directing knowledge from the offshore oil and gas industry to the offshore wind energy industry. This result is supported by the study of Owen-Smith and Powell (2004) wherein network positions were only important to form connections in the US biotech industry when actors are geographically distant, and network positions do not play a role when actors are geographically close. Our case supports this result, yet the reason is not geographical propinquity but the emergence of an institutional context at the regional level that guides relations between the two industries.

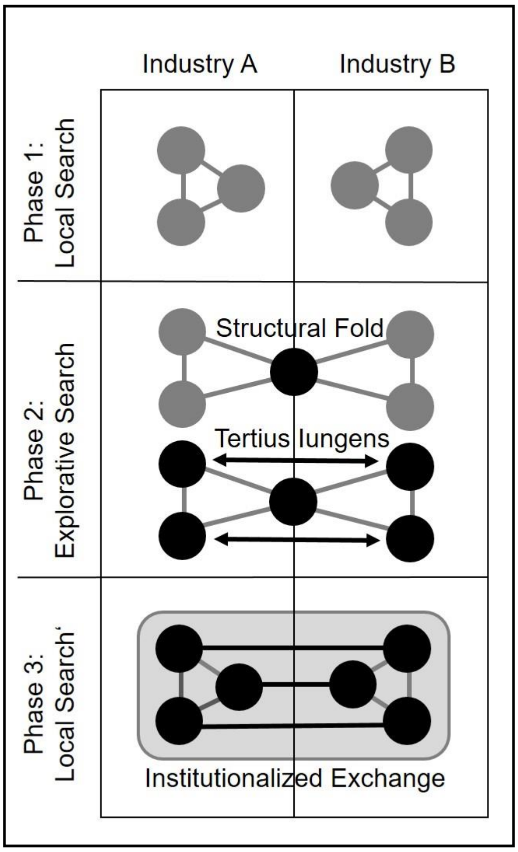

Figure 2: The Emergence of Relatedness

These results are condensed in Figure 2. The Figure shows the temporal sequence of three phases: local search (which ignores the other industry), explorative search (which builds first connections to the other industry), and altered local search' (which regularly involves the other industry). It shows the different relational dynamics of the three phases and the importance of technological discontinuities that starts an industry wide process of explorative search. We exclude the geographies of these processes, as they can take several different forms, depending on the locations of actors and industries involved. Yet, our study shows that the geography of relatedness results from the way it is institutionalized.

8. Conclusion

We started the paper with the question of how relatedness emerges between previously unrelated industries. Our fundamental assumption was that relatedness results from organizational search processes. When the default setting is organizationally local search, the other industry has to be regularly included in organizational search processes for two industries to be related. As a result, search has to change from organizationally local search (which ignores the other industry) to local search’ (which includes the other industry).

The case study on the offshore wind energy industry and the offshore oil and gas industry in Esbjerg revealed that the transformation of search from local search to local search’ follows a three phase sequence: in the first phase, organizationally local search processes were not sufficient to solve an industry specific problem; in the second phase, firms searched exploratively and those actors at structural folds applied tertius iungens strategies to connect actors from the two industries; and in the third phase, local search’ was institutionalized. Thus, relatedness emerged upon an institutionalization of search processes.

Besides explaining how relatedness emerges, the case study also illustrates the particular geography that coincides with the emergence of relatedness. Relatedness was not caused by geographically bound Jacobs’ externalities. The dynamics that initiated the connection between the two industries took place between spatially dispersed actors. Geographical proximity between offshore oil and gas and offshore wind energy firms followed these dynamics and was rather a result than a facilitator. Yet, geographical proximity facilitated institutionalization of exchanges between the two industries when some offshore wind energy firms were already located in Esbjerg.

Additionally, this study allows deriving some policy implications for the creation of relatedness. Especially smart specialization policies intend to promote knowledge diffusion between regional industries (McCann and Ortega-Argilés 2015), and initiatives to support such diffusion would typically aim at building connections between different regional industries via common projects or provision of platforms for interaction. Our study suggests that this policy would be fruitful only if there are already connections between regional industries. Instead, policies that intend to start connections between two regional industries should aim at actors that are located at a structural fold. The study at hand showed that these actors can even be important, if they are not located outside the region.

Our case study also gives some insights regarding questions on the theoretical conception of relatedness, e.g., if both industries benefit from relatedness or if relatedness is asymmetrical, if relatedness describes similarity or complementarity (Boschma 2017). Regarding the question of symmetry versus asymmetry, our study indicates that this can only be answered considering the particular context. In our case, it was clear which problems in the offshore wind energy industry could be addressed by knowledge from the offshore oil and gas industry and knowledge diffused asymmetrically from offshore oil and gas to offshore wind energy. Later, knowledge exchange became more symmetrical, as firms in the offshore oil and gas industry applied knowledge produced in the offshore wind energy industry. We assume that relatedness that starts asymmetrical and becomes symmetrical might be a regular pattern. For symmetrical relatedness to emerge from the outset, there must be a coincidence of problems in two different industries that can only be solved with knowledge from the other industry. We suggest that this coincidence is the exception. Additionally, regular and pervasive interactions due to asymmetric knowledge flows might also reveal that the other industry has something to offer. As a result, relatedness might become symmetrical.

Another point refers to the question as to whether relatedness describes knowledge similarities or complementarities. In our study, search focused on areas in which the other industry had specific capabilities, like maintenance of offshore installations or production techniques. This search exploits knowledge complementarities. In areas where knowledge was similar as in offshore health and safety, a common knowledge base evolved. Yet, also in this area, relatedness started due to knowledge complementarities. Thus, we found both forms of relatedness in our study that even changed over time.

Our study also supports findings that suggest that non-industrial actors are important to connect different fields. Tanner's (2014) study on the fuel cell industry revealed that universities and research organizations were important in this respect. In our work, customers like DONG Energy and knowledge intensive business services like Rambøll, COWI and DNV were important actors.

As studies before, our study also finds strong support for the claim that relatedness between regional industries is an important driver for their evolution. In addition, we can reveal how relatedness takes different forms and evolves over time. Our study especially points out the particular conditions, network dynamics and geographies that coincide with the emergence of relatedness; things that are either taken for granted or neglected in studies on relatedness. We therefore support Boschma's (2017) plea for more qualitative studies on relatedness and regional diversification to further elaborate the conditions, actors and dynamics that are responsible for regional related diversification.

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Appendix

Name of actor	Type of actor	Industry affiliation	Located in Esbjerg	Participated in personal interview	Participated in focus group interview	Participated in personal and focus group interview
Phase 1						
A2Sea	Firm	Wind		X		
Aalborg University	Knowledge organization		X	X		
Blaaholm	Firm	Wind	X	X		
Bladena	Firm	Wind		X		
Business Development Esbjerg	Network organization		X	X		
Dong Energy	Firm	Oil and gas Wind	X	X		
Esbjerg Maritime Service	Firm	Oil and gas Wind	X	X		
Esvagt	Firm	Oil and gas Wind	X	X		
Force Technology	Firm	Oil and gas Wind	X	X		
Hub North	Network organization			X		
Liftra	Firm	Wind		X		
Lindø Offshore Renewables Center	Test facility	Wind		X		
MacArtney	Firm	Oil and gas Wind	X	X		
Maersk Oil	Firm	Oil and gas	X	X		
MHI Vestas Offshore Wind	Firm	Wind	X	X		
Ocean Team Group	Firm	Oil and gas Wind	X	X		
Offshore Energy	Network organization		X	X		
Port of Esbjerg	Firm	Oil and gas Wind	X	X		
Rambøll	Firm	Oil and gas	X	X		

		Wind				
Region of Southern Denmark	Government			X		
Semco Maritime	Firm	Oil and gas Wind	X	X		
Siemens Wind Power	Firm	Wind	X	X		
Sihm Højtryk	Firm	Oil and gas	X	X		
Technical University of Denmark	Knowledge organization			X		
Total Wind	Firm	Wind	X	X		
University of Southern Denmark	Knowledge organization		X	X		
Vattenfall	Firm	Wind	X	X		
Phase 2						
A2Sea	Firm	Wind		X		
Blue Water Shipping	Firm	Oil and gas Wind	X			X
Bureau Veritas	Firm	Oil and gas	X		X	
Business Development Esbjerg	Network organization		X	X		
Dong Energy	Firm	Oil and gas Wind	X			X
Lindvig Consulting	Firm	Wind		X		
Maersk Oil	Firm	Oil and gas	X	X		
Ocean Team Group	Firm	Oil and gas Wind	X		X	
Offshore Center Denmark	Network organization		X	X		
Offshore Energy	Network organization		X	X		
Port of Esbjerg	Firm	Oil and gas Wind	X			X
Rambøll	Firm	Oil and gas Wind	X			X
Region of Southern Denmark	Government			X		
Semco Maritime	Firm	Oil and gas	X			X

		Wind				
Siemens Wind Power	Firm	Wind	X	X		
University of Southern Denmark	Knowledge organization		X		X	